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Proposals for improvement of Annex I of Directive 92/43/EEC: Sardinia

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Abstract

The 'Habitats' Directive (HD 92/43/EEC) is one of the primary legal tools aiming at conserving nature in Europe. Due to the complex iter to revise it, the habitats listed in the Annex I have been seldom updated after the HD adoption. Basing on already available information and expert knowledge, this paper presents a preliminary list of relevant habitats occurring in Sardinia, not yet considered and worth to be placed in the Annex I. Two new habitat proposals, one habitat new for Italy, and nine new subtypes of already existing HD habitats are here described. Most of the proposed new habitats and subtypes have a limited distribution range, due to the high number of narrow, often endangered, endemic species that characterize them. Being neglected, they are consequently poorly investigated, inconstantly monitored and unprotected. Thus, the main aim of this paper is to promote their conservation through implementation of HD and its interpretation manuals.

Keywords

Annex I habitats, endemic species, European 'Habitats' Directive, habitat types, habitat subtypes, Mediterranean Basin, Natura 2000 network, neglected habitats

Introduction

The 'Habitats' Directive (92/43/EEC, henceforth: HD) is, together with the Birds Directive (79/409/EEC, amended by Directive 2009/147/EC), the primary legal tool for nature conservation policy in Europe (Maiorano et al. 2017). Since its adoption, it went through several updates and corrections concerning Annex I, which provides a list of the habitats of community interest. These habitats fall into at least one of these criteria: 1) are in danger of disappearance in their natural range; 2) have a small natural range due to their regression or because of their intrinsically restricted distribution area; 3) present outstanding examples of typical characteristics of one or more of the eleven European biogeographical regions (Evans 2010).

The list of habitats should be subject to updates and amendments to accompany technical and scientific progress as established in article 19 of the HD, each time new countries join the European Union (EU; Cardoso 2012).

Any changes, both new habitats introduction and names modification of existing habitats require a complex iter with the final approval by the European Parliament and the Council of Ministers. So far, there is considerable reluctance to revise the annexes. Nevertheless, pragmatic solutions have been accepted throughout the years, particularly in biogeographical seminars (Evans 2006). However, several criticisms and approximations remain in interpreting the habitat types caused by the highly heterogeneous description provided by the Interpretation Manual of EU Habitats (European Commission 2013). Indeed

for some of them, we have very detailed information (e.g., 5330); for others, too concise features (e.g., 6220*).

When additional habitats proposed by new member states were close to already listed habitats, the definition of the existing habitat was changed rather than adding a new habitat. EU accepted enlargement and amendment of new habitats for Eastern Europe (2004), Bulgaria, Romania (2007), and Croatia (2016). Some habitats initially considered restricted to one or a few countries are now recognized over a much more comprehensive range. For example, habitat '8240 Limestone pavements' initially considered only in Ireland, the United Kingdom, and Sweden when it joined the EU in 1995, is now recognized in six other countries (updated from Gaudillat 2008).

Despite all these efforts and solutions, some interesting habitats do not appear in Annex I but probably fall within the definition of 'habitats of community interest' (Evans 2006). This issue significantly affects the Mediterranean area because the habitat classification is biased towards central and northern Europe. Consequently, many habitats from southern Europe are poorly defined or neglected. Moreover, there are still many problems in the habitat types identification, especially when they do not appear in Annex I of the HD.

Some of the above issues arise from the poor knowledge of the composition or distribution of some habitat types, others from sometimes overlapping types. This paper presents a preliminary list of selected relevant habitats in a Mediterranean region, Sardinia, not yet considered and challenging to be placed in Annex I of the HD. Here we also propose solutions to bring more attention and increase the information to support the monitoring activities on the proposed habitats (Gigante et al. 2016; Bonari et al. 2021).

Considering that the option of establishing new habitat types is generally rejected (Evans 2010), we formulate some proposals to include them in already listed habitats, mainly introducing well-defined subtypes. However, this procedure was not always possible and, in these cases, new habitats have been proposed.

Materials and methods

The selection of habitats of potential conservation concerns was based on bibliographic data, unpublished data, and expert knowledge. In addition, several critical issues have been examined through a shared scientific discussion among authors, including the motivation to include the habitat in the list.

The diagnosis and syntaxonomy started from the current scientific knowledge supported by a long experience acquired in the field, based on the European Interpretation Manual (European Commission 2013) and the Italian Interpretation Manual of the HD (Biondi et al. 2009, 2012). The syntaxonomy has been checked and updated with particular reference to the frame proposed in the Italian Vegetation Prodrome (Biondi et al. 2014; Biondi and Blasi 2015), used as a general base adapted to local conditions in Sardinia.

We considered three different cases: a) new habitat proposals, e.g., habitats not yet considered in the HD; b) habitats new for Italy, e.g., already listed in the HD but not considered for Italy; c) new subtypes in existing HD habitats already reported for Italy.

For each proposal, we detailed the following aspects:

- Motivation of the proposal;
- Macrotype;
- Name the new habitat proposed (case a) or reference to an already existing reference habitat (case b and c);
- Diagnostic sentence of the new habitat (a) or the proposed (c), including biogeographical and bioclimatic information. For the habitats already existing and new for Italy (b), arrangement of the diagnostic sentence;
- Reference list of diagnostic species;
- Phytosociological arrangement (mainly at the alliance level);
- Dynamics and/or catenal contacts.

Plant taxonomy follows Bartolucci et al. (2018).

Results

As a result of our analysis, we present here: a) two new habitat proposals; b) one habitat new for Italy; c) nine new subtypes of already existing HD habitats. We also propose a new name for two of them, better fitting with the proposed subtypes and the new framework (Tab. 1).

a) New habitat proposals

MEDITERRANEAN HEATHS

Motivation: Despite the relevant biogeographical significance recognized to Ericaceae (Schwery et al. 2015) and to the species of the genus *Erica* (McGuire and Kron 2005; Désamoré et al. 2011), no clear identification exists in the HD for Mediterranean shrubs dominated by heaths (Ojeda 2009; European Commission 2013). In contrast, a wide variety of heath habitats is described under category 4 – Temperate heath and scrub and, particularly, the habitat 4030 – European dry heaths. Due to their historical and present biogeographic relevance (Beffa et al. 2016; Pedrotta et al. 2021), we propose including Mediterranean heaths as a new habitat within the macrotype 52. The communities in this habitat are often unique and rich in plant species endemic and/or with conservation concern, such as *Gennaria diphylla* and other orchids, and *Chamaerops humilis* in the thermophilous heaths (Bocchieri and Satta 1999; Biondi and Bagella 2005; Bagella and Urbani 2006); *Amelanchier ovalis*, *Genista* spp., *Helleborus lividus* subsp. *corsicus*, *Ribes multiflorum* subsp. *sandalioticum* and *Rosa serafinii* in the montane heaths (Farris et al. 2007a; Chelli et al. 2019); *Osmunda regalis* and *Hypericum hircinum* in the hygrophilous heaths (Carta et al. 2014), among others.

Table 1. New habitat proposal (NH), habitats new for Italy (NHI) and new subtypes in already existing HD (NHS).

Code	Name of proposed type/subtype	Proposal
	Mediterranean heaths	NH
	Calaminarian vegetation of mining dumps, tailing dams and quarries	NH
2210	*Ephedra distachya* mantles on clay substrates	NHS
2220	Dunes with *Euphorbia terracina*	NHI
3170*	Dwarf vegetation with *Nananthea perpusilla*	NHS
5130	Mediterranean *Pruno-Rubion* communities	NHS
5330	Shrub communities surrounding Mediterranean temporary ponds	NHS
5410	*Helianthemum caput-felis* and *Viola arborescens* garrigues	NHS
6220*	Mediterranean semi-natural grasslands	NHS
6310	Wooded pasturelands	NHS
6420	Mediterranean tall humid herb grasslands	NHS
91E0*	*Rhamnus persicifolia* woodlands	NHS

This habitat can be referred to the CORINE biotope F5.22 – Dwarf ericoid shrubs (Lapresa et al. 2004).

Macrotype: 52 - Mediterranean arborescent matorral.

New habitat proposed: Mediterranean communities dominated by species of the genus *Erica*. We recognized in Sardinia four subtypes (1–4).

Diagnostic sentence: Subtype 1) calcifuge thermophilous heaths on acidic substrata from thermo- to lower meso-Mediterranean belts; subtype 2) calciphilous thermophilous heaths on sedimentary substrata from thermo- to lower meso-mediterranean belts; subtype 3) montane heaths from upper meso-mediterranean to supra-temperate sub-mediterranean variant) belts; subtype 4) hygrophilous heaths, from thermo- to supra-mediterranean belts, along streams, mainly on acidic soils.

Reference list of diagnostic species: Subtype 1) *Erica arborea*, *Erica scoparia*; subtype 2) *Erica multiflora*; subtype 3) *Erica arborea*, *Erica scoparia*, *Genista* spp., *Rosa serafinii*; subtype 4) *Erica terminalis*, *Carex microcarpa*, *Hypericum hircinum*, *Osmunda regalis*.

Phytosociological arrangement: Subtype 1) *Ericion arboreae* (Rivas-Martínez ex Rivas-Martínez, Costa & Izco 1986) Rivas-Martínez 1987; subtype 2) *Oleo-Ceratonion siliquae* Br.-Bl. ex Guinochet & Drouineau 1944 em. Rivas-Martínez 1975; subtype 3) *Ericion arboreae* (Rivas-Martínez ex Rivas-Martínez, Costa & Izco 1986) Rivas-Martínez 1987; subtype 4) *Pruno-Rubion ulmifolii* O. Bolòs 1954 (Rivas-Martínez et al. 2002; Biondi et al. 2014).

Dynamics and contacts: Contacts with all other communities involved in the vegetation series: anthropogenic herb-dominated communities of *Stellarietea mediae* and *Polygono-Poetea annuae* Rivas-Martínez 1975; fringes of *Galio-Urticetea* Passarge ex Kopecký 1969 and *Trifolio medii-Geranietea sanguinei* Müller 1962; dwarf shrub communities of *Cisto-Lavanduletea* Br.-Bl. in Br.-Bl., Molinier & Wagner 1940 and *Rosmarinetea officinalis* Rivas-Martínez, Fernández-González, Loidi, Lousã & Penas 2001; shrub communities of *Rhamno-Prunetea* Rivas-Goday & Borja ex Tüxen 1962 and *Quercetea ilicis* Br.-Bl. ex A. & O. Bolòs 1950 (*Pistacio lentisci-Rhamnetalia alaterni* Rivas-Martínez 1975); woods of *Querco roboris-Fagetea sylvaticae* Br.-Bl. & Vlieger in Vlieger 1937 and *Quercetea ilicis* (Bacchetta et al. 2009). The subtypes 1 and 3 are in contact with garrigues of *Teucrion mari* Gamisans & Muracciole 1984, *Cisto-Lavanduletea* (including montane aspects referred to *Carici-Genistetea lobelii* Klein 1972) (Valsecchi 1994; Farris et al. 2007a); subtype 2 with communities of *Rosmarinion officinalis* Br.-Bl. ex Molinier 1934 (incl. *Rosmarino-Ericion* Br.-Bl. 1931); subtype 4 with edaphohygrophilous woods of *Hyperico hircini–Alnenion glutinosae* Dierschke 1975, with a Tyrrhenian distribution (Dierschke 1975; Angius and Bacchetta 2009), and rhizophytic vegetation of *Caricion microcarpae* Gamisans 1975 (Bacchetta and Mossa 2004).

CALAMINARIAN VEGETATION OF MINING DUMPS, TAILING DAMS AND QUARRIES

Motivation: Natural revegetated post-mining dumps, tailing dams and quarries may act as important secondary habitats and can be considered a potential complement to existing protected ones (e.g., Angiolini et al. 2005; Řehounková et al. 2020). Due to the extreme and peculiar environmental conditions occurring there, the biological communities established on these substrates are often unique and rich in endemic plant species. Several threatened plants, such as *Linum muelleri* (a species listed in the Annex II of HD) or *Iberis integerrima*, are particularly adapted or even exclusive to this habitat. It might also support or be in contact with suitable conditions for different animals of conservation interest, such as birds, bats, amphibians and reptilians (Isaia et al. 2011; Lunghi et al. 2020). At the same time, the conservation and sustainable management of this habitat might facilitate the stabilization and phytoremediation of the contaminated substrata (Bacchetta et al. 2015, 2018; Boi et al. 2020). This habitat is present across Europe in different biogeographic and bioclimatic regions and further several subtypes with different species at the regional level can be included.

Macrotype: 81 – Scree.

New habitat proposed: Calaminarian vegetation of mining dumps, tailing dams and quarries. We recognized in Sardinia one subtype.

Diagnostic sentence: Mediterranean communities dominated by suffruticose chamaephytes and hemicryptophytes, specifically adapted to extreme environments determined by long-term historical mining activities, growing on soils often characterized by medium to very high levels of heavy metals (e.g., lead and zinc). Edaphic conditions can vary from gross-grained, hard-sloping dumps to impermeable and temporally inundated fine-grained deposits.

Reference list of diagnostic species: *Echium anchusoides*, *Epipactis helleborine* subsp. *tremolsii*, *Euphorbia pithyusa* subsp. *cupanii*, *Helichrysum microphyllum* subsp. *tyrrhenicum*, *Iberis integerrima*, *Limonium merxmuelleri* subsp. *merxmuelleri*, *Linum muelleri*, *Lysimachia monelli*, *Ptilostemon casabonae*, *Santolina insularis*, *Scrophularia canina*.

Phytosociological arrangement: *Ptilostemono casabonae-Euphorbion cupanii* Angiolini, Bacch., Brullo, Casti, Giusso Del Galdo & Guarino 2005 and, partially, *Teucrion mari* Gamisans & Muracciole 1985 (Bacchetta et al. 2007a).

Dynamics and contacts: Contacts with therophytic grasslands of *Tuberarion guttatae* Br.-Bl. 1931 or, when roots can stabilize soils and the concentration of heavy metals decreases, with garrigues of *Cisto-Lavanduletea* Br.-Bl. in Br.-Bl., Molinier & Wagner 1940, shrubs and micro-forests of the *Pistacio-Rhamnetalia alaterni* Rivas-Martínez 1975 and *Quercetalia ilicis* Br.-Bl. ex Molinier 1934 (Bacchetta et al. 2007b). Especially in temporally inundated fine-grained deposits, it can also be in contact with helophytic communities of *Phragmitetalia australis* Koch 1926, while, in other contexts, with different rocky habitats and caves.

b) Habitat new for Italy

DUNES WITH *EUPHORBIA TERRACINA*

Motivation: There is increasing evidence of the continuous loss and degradation of Mediterranean coastal habitats, particularly those located on dunes, affected by severe impacts from mass tourism (Sperandii et al. 2021). Therefore, it is urgent to protect the remnant well-preserved dune habitats and those with average conservation status, supporting future conservation and restoration actions. The Mediterranean formations on dunes with *Euphorbia terracina*, included in the HD with the code 2220, are a good example of this situation. This habitat has been reported for a single Italian site in Veneto (Petrella et al. 2005). However, it was later wholly excluded from Italy because of its poor conservation relevance (Biondi et al. 2009). Here, we underline the opportunity (previously raised by Farris et al. 2007b) to refer to this habitat perennial herb communities often growing on disturbed Mediterranean dunes (Farris et al. 2013a), characterized by some species already mentioned by the Interpretation Manual of HD (European Commission 2013), and by several Boraginaceae of the genera *Echium* and *Anchusa*. This inclusion would justify conservation efforts on semi-degraded Mediterranean dunes, which can be recovered after appropriate management actions.

Macrotype: 22 – Sea dunes of the Mediterranean coast.

Reference habitat: 2220 – Dunes with *Euphorbia terracina*.

Diagnostic sentence: *Euphorbia terracina* and/or *Echium* spp. dominated psammophilous communities present in almost all Italian coastal dune systems. Rosette hemicryptophytes dominated communities represent the prevalent subtype when trampling is a relevant disturbance factor.

Reference list of diagnostic species: *Echium arenarium*, *E. sabulicola*, *Euphorbia terracina*, *Silene nicaeensis* and *S. subconica*. In Sardinia, the habitat is of particular interest for the endemic *Anchusa crispa* and *A. sardoa*, the first being a priority species of the Annex II of the HD.

Phytosociological arrangement: *Crucianellion maritimae* Rivas Goday & Rivas-Martínez 1958.

Dynamics and contacts: These communities are degraded aspects of *Crucianellion maritimae* at the transition and often in a patchy contact with annual herb communities belonging to *Alkanno-Maresion nanae* Rivas Goday ex Rivas Goday & Rivas-Martínez 1963 corr. (Rivas-Martínez et al. 2002; Biondi et al. 2014) and to the CORINE biotope B1.44 – Central-eastern Mediterranean stable coastal dunes (Lapresa et al. 2004). It can also be found in contact with usually very degraded fragments of perennial geophyte communities of *Ammophiletea* Br.-Bl. & Tüxen ex Westhoff, Dijk & Passchier 1946.

c) New subtypes in already existing HD habitats

EPHEDRA DISTACHYA MANTLES ON CLAY SUBSTRATES

Motivation: This habitat, very rare and prone to shrinkage due to coastal erosion (Biondi et al. 2009), represents the mantle step dynamically linked to *Juniperus* spp. communities. In Sardinia, it occurs on fine clay substrates along the coastal ponds or along the temporary retrodunal ponds (Fenu et al. 2012); it deserves a special interest the presence of species that generally live on the sand such as *Scrophularia ramosissima* and *Armeria pungens*, interesting taxa both from the phytogeographic and conservation points of view.

Macrotype: 22 - Sea dunes of the Mediterranean coast.

Reference habitat: 2210 - *Crucianellion maritimae* fixed beach dunes. We recognized in Sardinia one subtype.

Diagnostic sentence: Primary garrigues of the Mediterranean bioregion, with few species that develop mainly on the inland-facing slope of mobile dunes with stable and compact sands belonging to *Crucianellion maritimae* Rivas Goday & Rivas-Martínez 1958.

Reference list of diagnostic species: *Ephedra distachya*, *Helichrysum microphyllum* subsp. *tyrrhenicum*, *Scrophularia ramosissima* and *Armeria pungens*.

Phytosociological arrangement: Partially included in the coenosis described in Sardinia as *Ephedro-Helichrysetum tyrrhenici* Valsecchi & Bagella 1991 corr., belonging to *Crucianellion maritimae* Rivas Goday & Rivas-Martínez 1958 (Biondi and Bagella 2005; Biondi et al. 2014).

Dynamics and contacts: These formations are in contact with *Juniperus macrocarpa* and *J. turbinata* formations included in habitat 2250*, belonging to the alliance *Juniperion turbinatae* Rivas-Martínez (1975) 1987, and with the communities dominated by *Calamagrostis arenaria* subsp. *arundinacea* included in habitat 2120 in the inland-facing slopes of mobile dunes on consolidated and humified substrates.

DWARF VEGETATION WITH *NANANTHEA PERPUSILLA*

Motivation: Temporary wet habitats are among the most interesting in the Mediterranean bioclimatic region (Médail et al. 1998). Issues related to their detection and classification are due at least partly to their intrinsic characteristics and to the traits of the plants that they host (Bagella et al. 2016; Bagella et al. 2018). They cover minimal surface areas, are ephemeral, and show high variability in terms of duration of the flooding period. Furthermore, the species which colonize them are often inconspicuous (e.g., dwarf annuals or dwarf geophytes), exhibit a very short life cycle, and are often poorly known (Bagella et al. 2007). Among these habitats, the most interesting from a conservation point of view are those with shallow waters (a few cm) located on small areas, referred to as priority habitat 3170*. However, the description of this habitat refers exclusively to communities of the class *Isoeto-Nanojuncetea* Br.-Bl. & Tüxen ex Westhoff, Dijk & Passchier 1946, thus excluding communities that are structurally similar but develop in small coastal ponds where the marine aerosol reaches. In these contexts, paucispecific communities, characterized by *Nananthea perpusilla*, develop (Biondi et al. 2001). Although it is already included in the physiognomic reference combination of habitat 3170* (Biondi et al. 2009), the peculiarity of the coenoses in which this species becomes dominant is not sufficiently valued. We, therefore, propose to establish within habitat 3170* a subtype characterized by the presence of slightly brackish water.

Macrotype: 31 – Standing water.

Reference habitat: 3170* - Mediterranean temporary ponds. We recognized in Sardinia one subtype.

Diagnostic sentence: Mediterranean amphibious vegetation, dominated by small-sized therophytes and geophytes, with predominantly winter/early-spring phenology, linked to shallow-water temporary pond systems influenced by the presence of saltwater or marine aerosol, distributed in coastal areas of Sardinia and Corsica prone to thermo-mediterranean thermotype.

Reference list of diagnostic species: *Nananthea perpusilla*, *Bellium bellidioides*, *Hypochaeris glabra*, *Plantago bellardi*, *Romulea requienii*, *Senecio leucanthemifolius* subsp. *leucanthemifolius*.

Phytosociological arrangement: *Saginion maritimae* Westhoff, Leeuwen & Adriani 1962, *Saginetea maritimae* Westhoff, Leeuwen & Adriani 1962.

Dynamics and contacts: The communities included in this habitat in Sardinia take part of the coastal sigmetum *Euphorbio characiae-Junipero turbinatae* (Biondi et al. 2001; Biondi and Bagella 2005; Pisanu et al. 2014).

MEDITERRANEAN *PRUNO-RUBION* COMMUNITIES

Motivation: The Mediterranean formations belonging to the *Pruno spinosae-Rubion ulmifolii* O. Bolòs 1954 are not adequately considered in the HD. In Sardinia, they are referable to the CORINE biotope +31.8A – Submediterranean vegetation with *Rubus ulmifolius* (Lapresa et al. 2004). In Sardinia, they deserve a special interest for the presence of several endemics belonging to the genera *Rubus* and *Ribes*, which are exclusive to this habitat. Among them, *R. sardoum* is a priority species of the Annex II of the HD.

Macrotype: 51 - Sub-Mediterranean and temperate scrub.

Reference habitat: 5130 - *Juniperus communis* formations on heaths or calcareous grasslands. We recognized in Sardinia one subtype.

Diagnostic sentence: shrub deciduous meso-hygrophilous communities of the *Pruno spinosae-Rubion ulmifolii* of the Mediterranean bioregion.

Reference list of diagnostic species: The subtype is of particular interest for the presence of endemic plants belonging to the genera *Rubus* (*R. arrigonii*, *R. laconensis*, *R. limbarae*, and *R. pignattii*) and *Ribes* (*R. multiflorum* subsp. *sandalioticum* and *R. sardoum*).

Phytosociological arrangement: *Pruno spinosae-Rubion ulmifolii*.

Dynamics and contacts: It can be in contact with wood communities of *Querco roboris-Fagetea sylvaticae* Br.-Bl. & Vlieger in Vlieger 1937 and *Quercetea ilicis* Br.-Bl. ex A. & O. Bolòs 1950 (Bacchetta et al. 2009) and with hygrophilous grasslands of the *Molinio-Arrhenatheretea* Tüxen 1937, and woodlands of the *Osmundo-Alnion glutinosae* (Biondi et al. 2002; Farris et al. 2007a; Biondi et al. 2009).

SHRUB COMMUNITIES SURROUNDING MEDITERRANEAN TEMPORARY PONDS

Motivation: These formations dominated by *Myrtus communis* and *Oenanthe pimpinelloides* are very rare transitional formations between Mediterranean temporary ponds and Mediterranean maquis representing a buffer area (Bagella et al. 2009).

Macrotype: 53 - Thermo-Mediterranean and pre-steppe brush.

Reference habitat: 5330 - Thermo-Mediterranean and pre-desert scrub. We recognized in Sardinia one subtype.

Diagnostic sentence: Maquis with sclerophyllous Mediterranean species, characteristic of the thermo-and meso-mediterranean bioclimatic belts, on different substrates (granites and effusive volcanites), typical of hydromorphic soils with a clay texture and slow drainage.

Reference list of diagnostic species: *Myrtus communis*, *Oenanthe pimpinelloides*, *Pistacia lentiscus*, *Pyrus spinosa*, *Rubus ulmifolius*, *Rubia peregrina*, *Phillyrea latifolia*, *Asparagus acutifolius*, *Smilax aspera*.

Phytosociological arrangement: In Sardinia, this community is referred to the *Oleo-Ceratonion siliquae* Br.-Bl. ex Guinochet & Drouineau 1944 em. Rivas-Martínez 1975, *Calicotomo-Myrtetum* Guinochet in Guinochet & Drouineau 1944 em. O. Bolòs 1962 (Farris et al. 2007b).

Dynamics and contacts: These formations establish contacts with Mediterranean amphibious vegetation of *Isoeto-Nanojuncetea* Br.-Bl. & Tüxen ex Westhoff, Dijk & Passchier 1946 (Isoetion Br.-Bl. 1936, *Cicendio-Solenopsion laurentiae* Brullo & Minissale 1998, *Preslion cervinae* Br.-Bl. ex Moor 1937), characterizing the Mediterranean temporary ponds (3170*) and with the communities of *Oleo-Ceratonion siliquae* Br.-Bl. ex Guinochet & Drouineau 1944 em. Rivas-Martínez 1975.

HELIANTHEMUM CAPUT-FELIS AND *VIOLA ARBORESCENS* GARRIGUES

Motivation: Habitat 5410, present along the coasts of the western Mediterranean, widespread in the Iberian-Levantine coasts in Italy, has so far been reported only for the northern Sardinia and, sporadically, in the southern part of the island; if also the coastal garrigues with *Helianthemum caput-felis* and *Viola arborescens* were included, it would have a more continuous distribution along the coasts of Sardinia. These communities deserve a special interest due to the presence of several endemics such as *Polygala sinisica*, which is exclusive to this habitat, and other plants of phytogeographic interest, like *Polygala rupestris*, which, in Italy, is only present in these formations.

Macrotype: 54 – Phrygana.

Reference habitat: 5410 - West Mediterranean clifftop phryganas *(Astragalo-Plantaginetum subulatae)*. We recognized in Sardinia one subtype.

Diagnostic sentence: Coastal garrigues, generally localized on the top of the cliffs and adjacent rocky areas, in the thermo-mediterranean phytoclimatic belt.

Reference list of diagnostic species: In Italy, the habitat is of particular interest for several endemic vascular plants such as *Centaurea horrida*, *Astragalus tegulensis*, *A. terraccianoi*, *Polygala sinisica*, *Helichrysum microphyllum* subsp. *tyrrhenicum*, *Limonium lausianum*, *Genista sardoa* and *Genista corsica*. There are also numerous species of phytogeographic interest such as *Helianthemum caput-felis*, *Viola arborescens*, *Polygala rupestris* and *Coris monspeliensis*.

Phytosociological arrangement: Not yet defined. Putatively *Rosmarinetea officinalis* Rivas-Martínez, T.E. Diáz, F.Prieto, Loidi & Penas 2002.

Dynamics and contacts: Partially investigated for the northern Sardinia; some aspects are reported in the study of plant communities dominated by *Centaurea horrida* (Biondi et al. 2001; Farris et al. 2008) and in the Italian Interpretation Manual of the HD (Biondi et al. 2009).

MEDITERRANEAN SEMI-NATURAL GRASSLANDS

Motivation: The conservation value of the European traditional farming systems has been recognized for several decades because of the biodiversity levels they support and the socio-ecological values they provide (Bignal and McCracken 2000). Among traditional farming systems, semi-natural grasslands host high levels of plant diversity and habitat richness at different spatial scales (Biurrún et al. 2021), responding to different drivers such as grazing intensity, soil and topographical variables (Napoleone et al. 2021). Moreover, they support several ecosystem services (Bagella et al. 2020a). Mediterranean semi-natural grasslands are already included in the HD with the priority code 6220*- 'Pseudo-steppe with grasses and annuals of the *Thero-Brachypodietea*' but only one and half rows of explanation in the Interpretation Manual of EU Habitats is provided for Italy: "In Italy this habitat mainly exists in the South and on the islands (*Thero-Brachypodietea*, *Poetea bulbosae*, *Lygeo-Stipetea*)" (European Commission 2013). Several interpretations were proposed because of the scarcity of information and the complexity of recognizing this habitat in the field (Farris et al. 2007c, San Miguel 2008). Moreover, the class *Thero-Brachypodietea* Br.-Bl. in Br.-Bl., Emberger & Molinier 1947 is now considered as a synonym of the class *Lygeo-Stipetea* Rivas-Martínez 1978 (Rivas-Martínez et al. 2002; Biondi et al. 2014). Later, new contributions provided experimental and phytosociological evidence to discriminate pastures with conservation concern, belonging to *Poetea bulbosae* Rivas Goday & Rivas-Martínez in Rivas-Martínez 1978, from nitrophilous herb-dominated communities, belonging to *Stellarietea mediae* Tüxen, Lohmeyer & Preising ex von Rochow 1951 (Farris et al. 2010). The high conservation value of supra-mediterranean and supra-temperate sub-mediterranean humid pastures referred to the *Cynosurion cristati* Tüxen 1947 of the *Molinio-Arrhenatheretea* Tüxen 1937 was also underlined (Farris et al. 2013b). Therefore, we propose changing the name of the habitat to "Mediterranean semi-natural grasslands" in which several subtypes can be considered.

Macrotype: 62 - Semi-natural dry grasslands and scrubland facies.

Reference habitat: 6220* Pseudo-steppe with grasses and annuals of the *Thero-Brachypodietea*.

New name proposed: Mediterranean semi-natural grasslands. We recognized in Sardinia five subtypes (1–5).

Diagnostic sentence: Thermo- to supra-mediterranean (up to supra-temperate sub-mediterranean), mostly open, annual and perennial grasslands. Subtype 1) Short-grass annual grasslands rich in therophytes and small geophytes on oligotrophic soils; subtype 2) thermo-mediterranean arid to dry, tall size, perennial grasslands; subtype 3) meso-mediterranean dry to subhumid, medium size, perennial grasslands; subtype 4) thermo- to supra-mediterranean (up to supra-temperate sub-mediterranean) pastures rich in therophytes and geophytes; subtype 5) supra-mediterranean to supra-temperate perennial pastures, rich in endemics and boreal-temperate taxa.

Reference list of diagnostic species: Subtype 1) *Brachypodium distachyon*, *Tuberaria guttata*; subtype 2) *Hyparrhenia hirta*, *Lygeum spartum*; subtype 3) *Brachypodium retusum*, *Dactylis glomerata* subsp. *hispanica*; subtype 4) *Poa bulbosa*, *Ranunculus paludosus*, *Trifolium subterraneum* (in Sardinia *Crocus minimus*, *Ornithogalum corsicum* and *Romulea requienii* differentiate the endemic suballiance *Ornithogalo corsici-Trifolienion subterranei* Farris, Rosati, Secchi & Filigheddu, 2013); subtype 5) *Agrostis capillaris*, *Cynosurus cristatus*, *Danthonia decumbens*, *Festuca morisiana* subsp. *morisiana*, *Lotus corniculatus* subsp. *alpinus*, *Oenanthe lisae*, *Ranunculus cordiger*. Each subtype can be referred to one or more CORINE biotopes: subtype 1) E1.A - Mediterranean arid grasslands, from acidophilous to neutrophilous, with low cover; subtype 2) E1.42 - *Lygeum spartum* steppe and E1.43 - Mediterranean steppe dominated by tall *Graminaceae*; subtype 3) E1.31 – western-Mediterranean xeric grasslands; subtype 4) E1.32 – south-western-Mediterranean stable pastures; subtype 5) E1.51 - montane supra-mediterranean steppe, E1.72 – grasslands with *Agrostis* spp. and *Festuca* spp. and E2.14 – multi-specific communities of flooded grasslands (Lapresa et al. 2004).

Phytosociological arrangement: Subtype 1) *Helianthemetea guttati* (Br.-Bl. in Br.-Bl., Roussine & Nègre 1952) Rivas Goday & Rivas-Martínez 1963 em. Rivas-Martínez 1978; subtype 2) *Lygeo-Stipetea*; subtype 3) *Brachypodio ramosi-Dactyletalia hispanicae* Biondi, Filigheddu & Farris 2001 (*Artemisietea vulgaris* Lohmeyer, Preising & Tüxen ex von Rochow 1951); subtype 4) *Poetea bulbosae*; subtype 5) *Cynosurion cristati* (*Molinio-Arrhenatheretea*) (Farris et al. 2007c, 2013).

Dynamics and contacts: The communities included in this habitat take contact with all other communities involved in the vegetation series: annual anthropogenic herb communities of *Stellarietea mediae* and grasslands of *Polygono-Poetea annuae* Rivas-Martínez 1975; fringe communities of *Galio-Urticetea* Passarge ex Kopecký 1969 and *Trifolio medii-Geranietea sanguinei* Müller 1962; dwarf shrub communities of *Cisto-Lavanduletea* Br.-Bl. in Br.-Bl., Molinier & Wagner 1940 and *Rosmarinetea officinalis* Rivas-Martínez, Fernández-González, Loidi, Lousã & Penas 2001; shrub communities of *Rhamno-Prunetea* Rivas-Goday & Borja ex Tüxen 1962 and *Quercetea ilicis* Br.-Bl. ex A. & O. Bolòs 1950 (*Pistacio lentisci-Rhamnetalia alaterni* Rivas Martínez 1975); wood communities of *Querco roboris-Fagetea sylvaticae* Br.-Bl. & Vlieger in Vlieger 1937 and *Quercetea ilicis* Br.-Bl. ex A. & O. Bolòs 1950 (Bacchetta et al. 2009).

MEDITERRANEAN WOODED PASTURELANDS

Motivation: Shade is a biotic filter and, under a novel climate, we need to consider the presence or absence of forest shade, as species are likely to respond individually only within their forest or non-forest biome, and not across biomes (Pausas and Bond in press). Mediterranean dehesas with evergreen *Quercus* spp., already included in the HD with the code 6310, are well known to provide high levels of biodiversity (Rossetti et al. 2015) and ecosystem services (Seddaiu et al. 2018). However, there is increasing evidence that wooded pastures belong to several phytosociological types (Bergmeier et al. 2010). Moreover, the highest diversity and area of Italian silvopastoral systems (wooded pastures, grazed woodlands) is in Sardinia (Paris et al. 2019). Therefore, we propose changing the name of the habitat to "Mediterranean wooded pasturelands" in which several subtypes can be included. As a consequence, the macrotype 63 – Sclerophyllous grazed forests should be expanded as "Wooded pasturelands", to host several habitats corresponding to the main groups proposed by Bergmeier et al. (2010): Hemiboreal and boreal wood-pastures, Nemoral old-growth wood-pastures, Nemoral scrub and coppice wood-pastures, Meridional old-growth wood-pastures = Mediterranean wooded pasturelands, Meridional scrub and coppice wood-pastures.

Macrotype: 63 - Sclerophillous grazed forests (dehesas).

Reference habitat: 6310 – Dehesas with evergreen *Quercus* spp.

New name proposed: Mediterranean wooded pasturelands. We recognized in Sardinia five subtypes (1–5).

Diagnostic sentence: Mediterranean wooded pasturelands with at least 20% tree cover. When at least 25% of the trees can be considered monumental, the habitat should have a priority status.

Reference list of diagnostic species: Subtype 1) wooded pasturelands dominated by evergreen *Quercus* spp.; subtype 2) wooded pasturelands dominated by wild olive and carob trees; subtype 3) wooded pasturelands dominated by junipers; subtype 4) wooded pasturelands dominated by deciduous oaks; subtype 5) wooded pasturelands dominated by other trees, on small areas but with high phytogeographic meaning (*Acer*, *Celtis*, *Fraxinus*, *Ilex*, *Ostrya*, *Taxus*). All these subtypes can be referred to the CORINE biotope E7.3 – Iberian wooded pasturelands (dehesa) (Lapresa et al. 2004).

Phytosociological arrangement: Subtype 1) *Clematido cirrhosae-Quercenion ilicis* Bacchetta, Bagella, Biondi, Farris, Filigheddu & Mossa 2004 of the alliance *Fraxino orni-Quercion ilicis* Biondi, Casavecchia & Gigante 2003; subtype 2) *Oleo-Ceratonion siliquae* Br.-Bl. ex Guinochet & Drouineau 1944 em. Rivas-Martínez 1975; subtype 3) *Juniperion turbinatae* Rivas-Martínez 1975 corr.; subtype 4) suballiance *Paeonio corsicae-Quercenion ichnusae* Bacch., Biondi, Farris, Filigheddu & Mossa 2004 corr. of the alliance *Pino calabricae-Quercion congestae* Brullo, Scelsi, Siracusa & Spampinato 1999; subtype 5) several alliances included in the classes *Querco roboris-Fagetea sylvaticae* Br.-Bl. & Vlieger in Vlieger 1937 and *Quercetea ilicis* Br.-Bl. ex A. & O. Bolòs 1950 (Bacchetta et al. 2009). The pasture communities are included in *Echio plantaginei-Galactition tomentosae* O. Bolòs & Molinier 1969 of *Stellarietea mediae* Tüxen, Lohmeyer & Preising ex von Rochow 1951, and *Ornithogalo corsici-Trifolienion subterranei* Farris, Secchi, Rosati & Filigheddu 2013 of *Poetea bulbosae* Rivas Goday & Rivas-Martínez in Rivas-Martínez 1978 (Farris et al. 2013b).

Dynamics and contacts: The communities included in this habitat take contact with all other communities involved in the vegetation series: annual and perennial herb communities of the *Helianthemetea guttati* (Br.-Bl. in Br.-Bl., Roussine & Nègre 1952) Rivas Goday & Rivas-Martínez 1963 em. Rivas-Martínez 1978, *Poetea bulbosae* Rivas Goday & Rivas-Martínez in Rivas-Martínez 1978, *Molinio-Arrhenatheretea* Tüxen 1937 and *Stellarietea mediae* Tüxen, Lohmeyer & Preising ex von Rochow 1951; fringe communities of *Galio-Urticetea* Passarge ex Kopecký 1969 and *Trifolio medii-Geranietea sanguinei* Müller 1962; dwarf shrub communities of *Cisto-Lavanduletea* Br.-Bl. in Br.-Bl., Molinier & Wagner 1940 and *Rosmarinetea officinalis* Rivas-Martínez, Fernández-González, Loidi, Lousã & Penas 2001; shrub communities of *Rhamno-Prunetea* Rivas-Goday & Borja ex Tüxen 1962 and *Quercetea ilicis* Br.-Bl. ex A. & O. Bolòs 1950 (*Pistacio lentisci-Rhamnetalia alaterni* Rivas-Martínez 1975); wood communities of *Querco roboris-Fagetea sylvaticae* Br.-Bl. & Vlieger in Vlieger 1937 and *Quercetea ilicis* Br.-Bl. ex A. & O. Bolòs 1950 (Bacchetta et al. 2009).

MEDITERRANEAN TALL HUMID HERB GRASSLANDS

Motivation: Part of the Mediterranean tall humid herb grasslands, especially in the western part of the basin, cannot be included in the presently described habitat 6420, although they share several species and have a similar physiognomic structure, ecology and distribution of the grasslands of the *Molinio-Holoschoenion* (=*Agrostio stoloniferae-Scirpoidion holoschoeni* De Foucault 2012). They are indeed differentiated by taxa, such as *Hordeum bulbosum* or the rare *Ranunculus macrophyllus*. Therefore, they are attributable to *Gaudinio fragilis-Hordeion bulbosi* Galàn, Deil, Haug & Vicente 1997, within the same *Molinio-Arrhenatheretea* Tüxen 1937 class. These communities are the habitat where a wide range of arthropods and the herpeto-avifauna live, feed and breed. Some geophytes of conservation concern in Sardinia are also frequent, such as *Anacamptis laxiflora* and *Leucojum aestivum* subsp. *pulchellum*. The conservation value of these grasslands has also been underlined for the Iberian and Italian peninsulas (Deil et al. 1997; Cano-Ortiz et al. 2009). The habitat 6420 is shrinking mainly due to the abandonment of traditional extensive grazing practices and/or land reclamation (Gigante and Buffa 2016). Here, we propose changing the habitat's name to 'Mediterranean tall humid herb grasslands' in which different alliances can be included rather than the only *Molinio-Holoschoenion*.

Macrotype: 64 - Semi-natural tall-herb humid meadows.

Reference habitat: 6420 - Mediterranean tall humid herb grasslands of the *Molinio-Holoschoenion*.

New name proposed: Mediterranean tall humid herb grasslands. We recognized in Sardinia one subtype.

Diagnostic sentence: Secondary mesophilous pastures, generally unmown, dominated by tall grasses that grow on mesotrophic, nutrient-rich soils with a good seasonal water supply (temporarily flooded in winter). They occur in the western Mediterranean, in inland hills and plains, mainly within the meso-mediterranean thermotype.

Reference list of diagnostic species: *Phalaris coerulescens*, *Hordeum bulbosum*, *Anacamptis laxiflora*, *Ranunculus macrophyllus*, *Leucojum aestivum*, *Carex divisa*, *Carex otrubae*, *Anthoxanthum aristatum*, *Serapias* spp., *Lythrum salicaria*.

Phytosociological arrangement: *Gaudinio fragilis-Hordeion bulbosi.*

Dynamics and contacts: The persistence of this subtype is, similarly to the rest of the habitat 6420, affected by non-intensive grazing. Without such agro-pastoral activities, these would be replaced by meso-hygrophilous shrub communities, such as the ones referable to the alliance *Pruno spinosae-Rubion ulmifolii* O. Bolòs 1954, in dynamic contact with deciduous forest communities dominated by *Ulmus*, *Fraxinus* and *Populus* spp. The subtype is in topographic contact with most of the helophytic plant communities reported for the rest of the habitat in the Italian Manual (Biondi et al. 2009). In inland Sardinian contexts, it is also often in contact with mesophilous cork-oak series on alluvial clay soils (Bacchetta et al. 2009).

RHAMNUS PERSICIFOLIA WOODLANDS

Motivation: The habitat 91E0* includes alluvial, riparian and marshy woodlands dominated by *Alnus* spp., *Fraxinus excelsior*, *F. oxycarpa* and *Salix* spp. It develops on flooded alluvial soils: along the waterways in the mountain and hilly sections; in the plain or on the shores of lakes and in areas with water stagnation. It prefers a temperate macroclimate, but penetrates also into the Mediterranean, where the humidity is high. It is present in almost all Italian regions; being more frequent in the Alpine and Continental bioregions and more sporadic in the Mediterranean bioregion, where it is quite common only in Tuscany, Sardinia and Calabria. The proposed subtype, endemic to Sardinia, deserves a particular interest for the restricted distribution limited to the mountain areas of central Sardinia and for its uniqueness due to the presence of several narrow endemic plants. In Sardinia, the proposed subtype and another subtype, which includes the western Mediterranean riparian forests with *Alnus glutinosa* (*Osmundo-Alnion glutinosae* alliance defined by the Corine code 44.5; Biondi et al. 2009), would contribute characterizing the habitat 91E0* in detail, including woodlands of extreme conservation interest.

Macrotype: 91 - Forests of temperate Europe.

Reference habitat: 91E0* Alluvial forests with *Alnus glutinosa* and *Fraxinus excelsior* (*Alno-Padion*, *Alnion incanae, Salicion albae*). We recognized in Sardinia one new subtype.

Diagnostic sentence: Sardinian endemic meso-hygrophilous woodlands of the Mediterranean region dominated by *Rhamnus persicifolia*.

Reference list of diagnostic species: This subtype is of particular interest for the presence of many Sardinian endemic vascular plants belonging to the genus *Aquilegia* (*A. barbaricina*, *A. nugorensis*) as well as other rare

endemics such as *Rhamnus persicifolia* and *Ribes multiflorum* subsp. *sandalioticum*.

Phytosociological arrangement: *Pruno spinosae-Rubion ulmifolii* O. Bolòs 1954.

Dynamics and contacts: As reported in the study of Sardinian woodlands dominated by *Alnus glutinosa* (Angius and Bacchetta 2009) and the Italian interpretation manual of the 92/43/EEC Directive Habitats (Biondi et al. 2009).

Discussion and conclusions

This research aims to present a preliminary list of valuable vegetation types occurring in Sardinia and not currently adequately represented in any of the habitat types listed in Annex I of the HD, as a base to promote actions for their conservation.

Our proposals for improving the HD result from a careful review of the plant communities present in Sardinia based on already available information and expert knowledge.

Considering that any changes to Annex I, both new habitats and changes to the names of existing habitats, require a co-decision of the EU parliament and the council of ministers, these solutions are only applied if strictly necessary. Therefore, whenever possible, we defined new subtypes as this is the most preferable and feasible solution.

As expected, given the high number of endemic plant species that characterize the vascular flora of Sardinia, the proposed new habitats and subtypes mainly answer to the 'restricted distribution' criterion, which is one into which a habitat must fall to be a candidate to be included in the HD (Evans 2010). Thus, the narrow size of the habitats/subtypes proposed is mainly dependent on endemic plant species with very restricted distribution areas. Indeed, out of more than 100 taxa listed in the 'physiognomic reference combination', 34 are endemic. Of these, 20 are exclusive to the Sardinian flora (Arrigoni 2006-2015; Peruzzi et al. 2014; Bartolucci et al. 2018; Bagella et al. 2020b).

It is also worthy of attention that five species mentioned here, i.e. *Anchusa crispa*, *Centaurea horrida*, *Helianthemum caput-felis*, *Linum muelleri* and *Ribes sardoum* are included in the Annex II of the HD. Further animals from the same list might also benefit from the conservation of the proposed habitats and subtypes. Special attention should be thus paid to the habitats in which they develop.

The two new proposals are finalized to consider 'Mediterranean heath' and 'calaminarian vegetation of mining dumps, tailing dams and quarries' as new habitats, which cannot be included in any existing typologies. We suppose that 'calaminarian vegetation of mining dumps, tailing dams and quarries' is also present in other European areas with different floristic composition. Our proposal may be enlarged by adding several bioclimatically and biogeographically differentiated subtypes. The same new habitat might also include abandoned quarries, a similar context where communities of conservation interest were already depicted in several European countries (e.g., Mota et al. 2004; Gentili et al. 2011; Pitz et al. 2018). Also 'Mediterranean heaths', due to their peculiar and diversified composition, deserve in our opinion the inclusion in the HD as a new habitat with four different subtypes, defined according to their different soil and wetness conditions. The Sardinian *Pruno-Rubion* communities were instead proposed as a Mediterranean mesophilous subtype of the habitat 5130, with which share similar structural and ecological characteristics but a different floristic composition, enriched by the presence of some species of particular conservation interest. Other proposals regard specific transitional habitats, which are very vulnerable and often neglected for their peculiar position. It is the case of 'Dunes with *Euphorbia terracina*', already considered in Europe but not yet in Italy, '*Ephedra distachya* mantles on clay substrates', 'Dwarf vegetation with *Nananthea perpusilla*', and 'Shrub communities surrounding Mediterranean temporary ponds'. This last case is a straightforward example of the problematic attribution of transitional communities to an already existing reference habitat. 'Shrub communities surrounding Mediterranean temporary ponds' are in fact a transitional subtype between thermo-xerophilous conditions, which are typical of the habitat '5330 - Thermo-Mediterranean and pre-desert scrub', and the seasonally inundated conditions that charachterize the surrounded habitat '3170* - Mediterranean temporary ponds'. For the similar structure, distribution and shared species, 'Shrub communities surrounding Mediterranean temporary ponds' were thus debatably referenced as a subtype of the habitat 5330, despite their different ecology linked to moist conditions.

It is also challenging to solve the definitions of Mediterranean semi-natural grasslands and Mediterranean tall humid herb grasslands. Therefore, we identify different subtypes for these typologies and propose a new name for the two corresponding habitats (i.e., 6220* and 6420), typical examples of the brevity of description and scarcity of information given for many habitats by the Interpretation Manual (European Commission 2013). As far as wooded pastures are concerned, we hypothesized a more inclusive vision and not only limited to the presence of evergreen oaks, following previous authors (Bergmeier et al. 2010). However, even this vision necessarily implies a change in the name of habitat 6310 (and probably the macro-type 63).

Among the direct and concrete consequences of the failure to consider our proposals, the following should be the more relevant: they will not be mapped in the Natura 2000 network areas; they will not be targeted by specific measures; their conservation status will not be subject to the mandatory periodic monitoring and reporting actions under Article 17 of the HD; they will not be protected through the establishment of specific conservation areas.

Although we formulated our proposals looking at the regional scale, we expect many of our observations to reflect common situations in the Mediterranean area. We hope that synergies with other territories can strengthen them.

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